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Regulatory failures for nuclear safety – the bad example of Japan – implication for the rest of world

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ABSTRACT

Investigation before and after the Fukushima nuclear accident has revealed that the failures of Japan's nuclear regulatory system was also blame to the worst nuclear accident since Chernobyl. The Fukushima nuclear accident has served to remind us that nuclear safety regulatory failure is vulnerable to the potentially deadly combination of natural risk. It should be noted that nuclear regulatory failures are not unique to Japan, given the low efficiency of the International Atomic Energy Agency (IAEA). We are living in a nuclear world. We have no alternative but to learn the lessons from the Fukushima. Unfortunately, all signs do not seem to be promising. This was partly due to competing proposals from several countries without clear understanding of which ideas would help, and a lack of sustained leadership focused on building support for key initiatives beforehand. New actions to strengthen the nuclear safety should be derived upon a thorough assessment of the causes for Japan's nuclear regulatory failures, as well as a comparative analysis of the nuclear regulatory systems in Japan, the United States (the owner of most nuclear reactors in operation), and China (the owner of most nuclear reactors under construction). This article is addressed to conduct an analysis of the causes for Japan's nuclear regulatory failure, discuss the key deficits in the nuclear regulatory systems of the U.S. and China, and finally outline two main policy recommendations. Nuclear accident knows no boundaries. Strengthening our nuclear safety regulation is not an option but an imperative, thus ensuring that the 433 operational units of reactor run safely, as well as 65 proposed ones. March 11, 2012 is the first anniversary of the Fukushima accident. This provocative article that calls for action on upgrade nuclear safety regulation over the world is dedicated to commemorate the first anniversary of the Fukushima accident.

Contents

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1. Introduction

A magnitude 9.0 earthquake followed by an immense tsunami on March 11, 2011 crippled the cooling systems at the Fukushima Daiichi nuclear power plant in Japan, which caused the worst nuclear accident since the Chernobyl [1,2]. In addition to natural disasters, investigations before and after the Fukushima nuclear disaster have revealed that nuclear regulatory failures are also to blame for the Fukushima nuclear accident [1,3–15]. These Japan's regulatory documents have listed the Fukushima Daiichi nuclear power plant as one of the most trouble-prone nuclear facilities in Japan over last decade [5,6,8,10,16]. And Reuters uncovered that the Fukushima Daiichi power plant was rated the most hazardous nuclear facility in terms of Japan for worker exposure to radiation and one of the five worst nuclear plants in the world between 2004 and 2008 [17]. In the most recent case, in August 2010, employees at the Fukushima Daiichi Nuclear Power Plant, armed with plans for work on the Unit 6 reactor, instead began conducting work on the Unit 5 reactor. They then altered work plans on their own, leading to a mistake that rendered the unit's cooling system inoperable [6,15]. However, the Nuclear and Industrial Safety Agency (NISA), Japan's nuclear regulatory body still allowed its operation, and even approved it Unit 1 reactor for an extension of operation for another ten years in February 7, 2011, after the reactor ended its designed lifecycle [18].

The Fukushima nuclear accident has served to remind us that nuclear safety regulatory failure is vulnerable to the potentially deadly combination of natural risk. It should be noted that nuclear regulatory failures are not unique to Japan, given the low efficiency of the International Atomic Energy Agency (IAEA) [19]. In contrast to the IAEA's role in nuclear non-proliferation, nuclear safety measures are voluntarily adopted by individual countries or regions. In fact, on 21 March 2011, the IAEA Director General openly stated on March 21, 2011 that IAEA was not a "nuclear safety watchdog" [20].

We are living in a nuclear world (see Box 1). In such a dangerous world with nuclear risk, we have no alternative but to learn the lessons from the Fukushima. These weaknesses of the nuclear regulatory system must be fixed around the world.

Unfortunately, all signs do not seem to be promising, as exemplified by the June's IAEA ministerial meeting in June 2011 [34], and the United Nations' high-level meeting on nuclear safety and security on September 22 [35], in which few constructive proposals emerged. This was partly due to competing proposals from several countries without clear understanding of which ideas would help, and a lack of sustained leadership focused on building support for key initiatives beforehand [36]. New actions to strengthen the nuclear safety should be derived upon a thorough assessment of the causes for Japan's nuclear regulatory failures, as well as a comparative analysis of the nuclear regulatory systems in Japan, the United States (the owner of most nuclear reactors in operation), and China (the owner of most nuclear reactors under construction). To this end, the present article is intended to conduct an analysis of the causes for Japan's nuclear regulatory failure, discuss the key deficits in the nuclear regulatory systems of the U.S. and China, and finally outline two main policy recommendations.

2. Regulatory causes of the Fukushima nuclear accident

Worldwide Governance Indicators (WGI) developed by the World Bank shows that Japan has been rated well on governance relative to the most countries in the world, but in the bottom of countries of Organization for Economic Co-operation and Development [37,38]. Specifically, the Japanese government has been rated among the top 30 countries in the world on "Control of Corruption", "Government Effectiveness", and "Rule of Law" in recent

Box 1

Certainly, almost all of us would prefer maximizing the alternative to expanding the nuclear, in the wake of the Fukushima accident. However, many countries still maintain their plans for nuclear power expansion to meet energy demand and carbon reduction.

(i) **UK.** In October, 2011, the Weightman Report, authored by the UK's chief nuclear inspector Dr Mike Weightman, presented that UK nuclear plants were safe and government strategy for new plants was adequate. The report indicates that nuclear energy will be as a key part of UK's future energy mix.

(ii) **China.** China is currently building 27 new reactors – over 40% of the world's total 65 reactors under construction [21]. In March 16, 2011, China's State Council announced a temporary freeze on all nuclear projects currently under construction, pending a safety review, but did not mention anything about plans already approved. This decision may slow down nuclear construction, but should not stop it, thus would not hinder the long term nuclear energy growth [22,23].

(iii) **U.S.** There are 104 reactors – 25% of the world's reactor in operation – are running [24]. In "*Recommendations for Enhancing Reactor Safety in the 21st Century*" reported on July 12, 2011, the U.S. NR (Nuclear Regulatory Commission) concluded that continued operation and continued licensing activities do not pose an imminent risk to public health and safety [25].

(iv) **France.** Atomic energy produced about 75% of its electricity in France [24]. France president Nicolas Sarkozy officially supports nuclear expansion because of the "need to reduce carbon gas emissions" [26].

(v) **Japan.** Even as it has struggled to contain the world's worst nuclear accident in the last quarter-century, Japan still pledged to stay committed to atomic energy, and just scrutinized the ability of power plants to withstand earthquakes and tsunamis. Indeed, to meet the electricity demand of summer, Japan government in July conducted "stress tests" and restarted nuclear reactors suspended for regular inspections [27]. In addition, a nuclear reactor in western Japan began starting back up on November 1, 2011, the first reactor in the country resumed operations since the Fukushima nuclear disaster [28].

As of December 2011, Germany, Switzerland and Italy have decided to reject nuclear power. However, it is a gigantic challenge to fill the gap that the nuclear exit. For example, Germany clearly vowed to switch to renewable energy, calling for a "measured exit" from nuclear power by 2022. However, shutdown of reactors will result in higher prices of energy, electricity import from nuclear plants in France or Czech [29], boosting coal-fired power stations [30], and increasing carbon emission [31]. Maximizing alternatives, such as wind energy, is not an easy or cheap choice. Given that most of German wind is in the north, and many of its nuclear plant is in the south, a new massive grid of high-voltage cables, called the energy highway is required. The route goes through the Rennsteig, the center of Germany, where Germans come to hike in what they feel is the idyllic embodiment of their country. There is much opposition to the energy highway, which gives the government no less a political headache than the current anti-nuclear protest [32,33].

In total, 433 nuclear reactors in operation in 29 countries provided 14% of the world's electricity production [21]. 15 countries relied on nuclear energy to supply at least one-quarter of their total electricity [24]. As of December 2011, there are 65 units of reactor "under construction" in 14 countries [21]. It is safe to say that a world without nuclear energy is arduous, if not impossible in the near future.

Box 2
The Japan's regulatory system has been heavily influenced by the Confucian culture [42]. As a Confucian country, rigid social hierarchy has remained popular in Japan, although it has achieved industrialization, urbanization and modernization. Confucianism leads bureaucrats to see themselves as samurai and the business as serfs. And business voluntarily looks to government for guidance. This culture allowed the Japan's government to strongly influence business. Businesses worked hard not only for its stakeholder but also for targets set by the government [40,42]. The Japanese government so closely worked with its business sector, that Western observers have popularized this alliance as the "Japan Inc." [43]. Although some question that Japan still fits the "Japan Inc." after several reforms in the 1990s, there is little doubt that the relationship between government agencies and business remain close [41].

years [37]. Based on the data and information from peer-review papers, documents of IAEA and Japan's government, and reports of newspaper and magazine, we intend to discuss of those three areas in the Japan's nuclear regulatory system to analyze the causes for Japan's nuclear regulatory failure,

2.1. Control of corruption

Regulatory failure is inevitable if corruption is not averted or effectively controlled [39]. Unfortunately, corruption in the Japan's nuclear safety regulatory system roots in Japan's economy system. With the "Japan Inc." (see Box 2), amakudari (descend from heaven) and amaagari (ascent to heaven), an illegal revolving door, between many branches of the Japanese government and corporations has become a widespread practice. Amakudari allows government bureaucrats to take up lucrative positions at the companies they once oversaw when retired. On the other hand, amaagari, a less known practice, allows Japan's government agencies freely hired experts or person from industrial sectors [40,41]. To be sure, no industry is perhaps as rife with amakudari and amaagari as the nuclear power sector in Japan.

Amakudari: In a pattern reflective of the rigid hierarchy in Japan's regulatory agencies and nuclear utilities, the senior officials went to work at bigger nuclear utilities, while those of lower ranks ended up at smaller utilities. In addition, when one retired from the nuclear utilities, his junior from the regulation agency would take over what is known as the agency's "reserved seat" of cozy job at the nuclear utilities [4]. Just at Tokyo Electric Power Company (TEPCO), the operator of the Fukushima Daiichi Nuclear Power Plant, four former most senior officials from nuclear regulatory agencies successively served as vice presidents at this company from 1959 to 2010. In the most recent case, Toru Ishida became a senior adviser at TEPCO in January, 2011, just less than six months after retiring as the head of the Agency for Natural Resources and Energy, the ministry organization that promotes the nuclear industry [4].

Amaagari: Associated Press examined the business and institutional ties of 95 people currently at three main nuclear regulatory bodies (NISA, Atomic Energy Commission, or AEC, and Nuclear Safety Commission of Japan, or NSC). Overall, 26 of them have been affiliated either with the industry or groups that promote nuclear power, typically with government funding. Associated Press also came across 24 people with prior positions at those three regulatory bodies – one-third of whom had connections to industry or pro-nuclear groups [9].

Perhaps no one has illustrated the movement of amakudari and amaagari better than Tokio Kano. He joined TEPCO in 1957, became a leader in the utility's nuclear unit in 1989, and in 1998 entered Japan's parliament as a candidate for a seat given to the nation's largest business lobbying group. In parliament, Kano helped rewrite the national policy that enshrined nuclear as the energy of Japan's future. After two six-year terms, he returned to TEPCO as an adviser in July 2010 [44].

With such incestuous relationships between the nuclear regulators and nuclear utilities being regulated in place, inspections have been superficial. For example, after TEPCO was found to have fabricated repairs reports in 2002, the maximum fine that companies could be faced with for a false report has been raised to 100 million yen ($1.3 million). However, no utility has received this penalty; even TEPCO has never paid any fines related to falsifying records. What TEPCO did do in 2002 was clean house by firing four top executives. But three top executives of them later took jobs at companies conducting business with TEPCO [9,15].

2.2. Regulatory capture

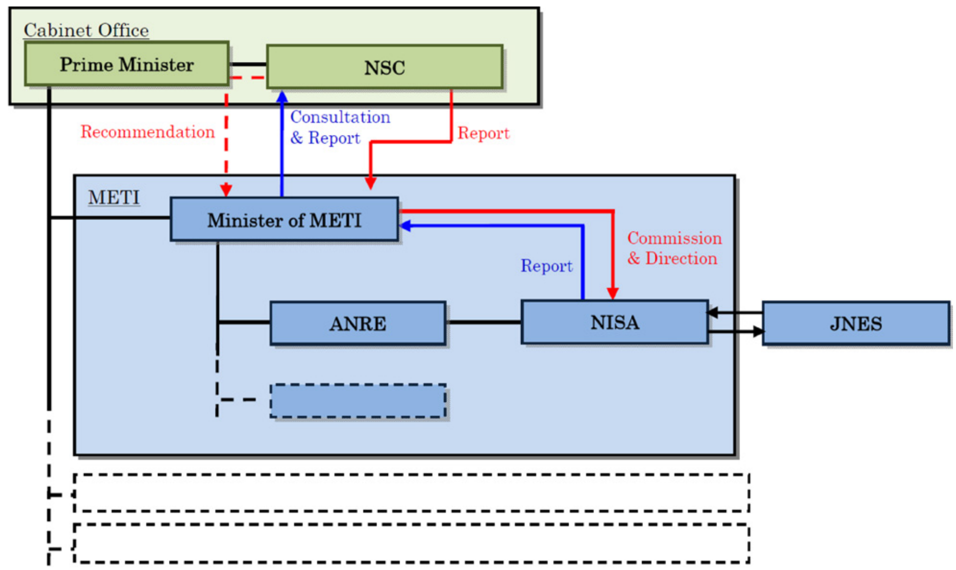
Regulatory capture – regulatory agencies come to be dominated by the industries regulated – also can lead to regulatory failure [45]. In our view, Japan's nuclear regulatory capture is derived from its regulatory structure. In Japan, there are three nuclear organizations: AEC, NSC and NISA [1]. But Japan's nuclear regulating system is mainly administered by NISA (see Fig. 1). Though it is charged with oversight, NISA is a division of the Ministry of Economy, Trade and Industry (METI), which is also responsible to promote nuclear industry (see Fig. 1). METI is in charge of with touting the benefits of nuclear energy, selling Japanese nuclear technology to other countries, and regulating domestic nuclear plant safety. In addition, NISA, METI and the nuclear power industry share common interests in promoting nuclear as a carbon-free energy source, which reduces Japan's heavy reliance on imported fossil fuel [4,9,38].

The promoter–regulator conflict of nuclear regulatory agency makes Japan unusual among nuclear users. The United States split those two functions since 1970s when its Atomic Energy Commission was closed. Currently, U.S. Department of Energy promotes nuclear power while the U.S. Nuclear Regulatory Commission handles safety. France separated those two functions through removing its nuclear regulator from the government bureaucracy and making it an independent authority.

The Japan's nuclear regulatory structure leads NISA to become a member of the community seeking profits from nuclear power. As a result regulatory agency lack of independence and authority to fulfill their oversight, supervisory and enforcement functions. Indeed, NISA did not see its role of watchdog for nuclear safety and public interest to judge whether the nuclear reactors were operating sufficiently safe. The inspection process (see Fig. 2) has been comprised by the NISA. Under Japan's nuclear regulatory system, NISA carries out plant inspections once every 13 months and checks on safety measures every quarter. There are no surprise inspections, though inspectors visit plants routinely. Utilities have been ordered to shut plants temporarily after safety problems and cover-up scandals [44]. The aftermath of the worst nuclear accident since Chernobyl may finally persuade a nation that is promoter–regulator conflict can split those two functions.

2.3. Rule of safety regulation

Safety regulatory failure occurs when the safety rulemaking is deeply flawed, although the legislative framework for nuclear safety is seems good. Indeed, Japan has established a comprehensive nuclear safety law and regulation system (see Fig. 3). The *Atomic Energy Basic Act* enacted in 1955, which is at the top of the framework and defines basic philosophy for utilization of nuclear energy. The *Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors* enacted in 1957, which provides



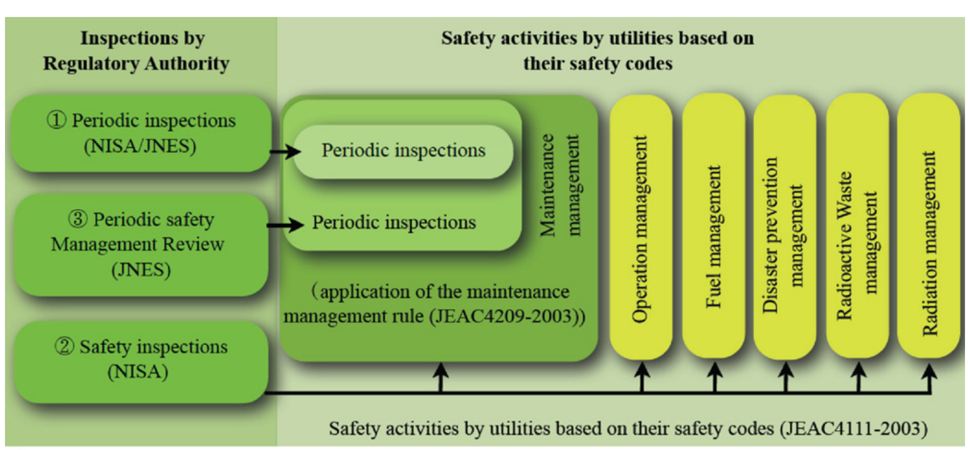
Notes: **NSC** - Nuclear Safety Commission of Japan
METI - Ministry of Economy, Trade and Industry
ANRE - Agency for Natural Resources and Energy
NISA - NISA Nuclear and Industrial Safety
JNES - Japan Nuclear Energy Safety Organization

Fig. 1. Position of NISA in the government.

Source: [1].

for safety regulation by the Government and obligations of the operators. And the *Law for Prevention of Radiation Hazards due to Radioisotopes*, etc., the *Electricity Business Act*, and the *Act on Special Measures Concerning Nuclear Emergency* have been put in place [1] (see Fig. 3).

However, Japan's safety rulemaking is deeply flawed. Because NISA lacks full-time technical experts to draw up comprehensive regulations, it depended largely on retired or active engineers from nuclear-industry-related companies to set rulemaking. Some rulemakings that can enhance nuclear safety had been lagged [3,4,9]. For example, in 2007, NISA's committees began focusing on seismic dangers after an earthquake in northwestern Japan caused radioactive leaks, a minor fire and wall cracks at Kashiwazaki-Kariwa nuclear plant operated by TEPCO. Six "subgroup committees" organized by NISA looked at earthquakes and tsunami standards. The subgroups reported to three "working groups," which held bigger



Notes:

① Periodic Inspections: Inspect compatibility on technical standard requirements for safety priority SSCs

② Safety inspections: Inspect whether utility's activities (maintenance, operation and fuel management, etc) are in compliance with their safety codes.

③ Periodic safety Management Review: Inspect procedures and organization for periodic inspections

Fig. 2. Inspection process in Japan's nuclear regulatory system.

Sources: [46,47].

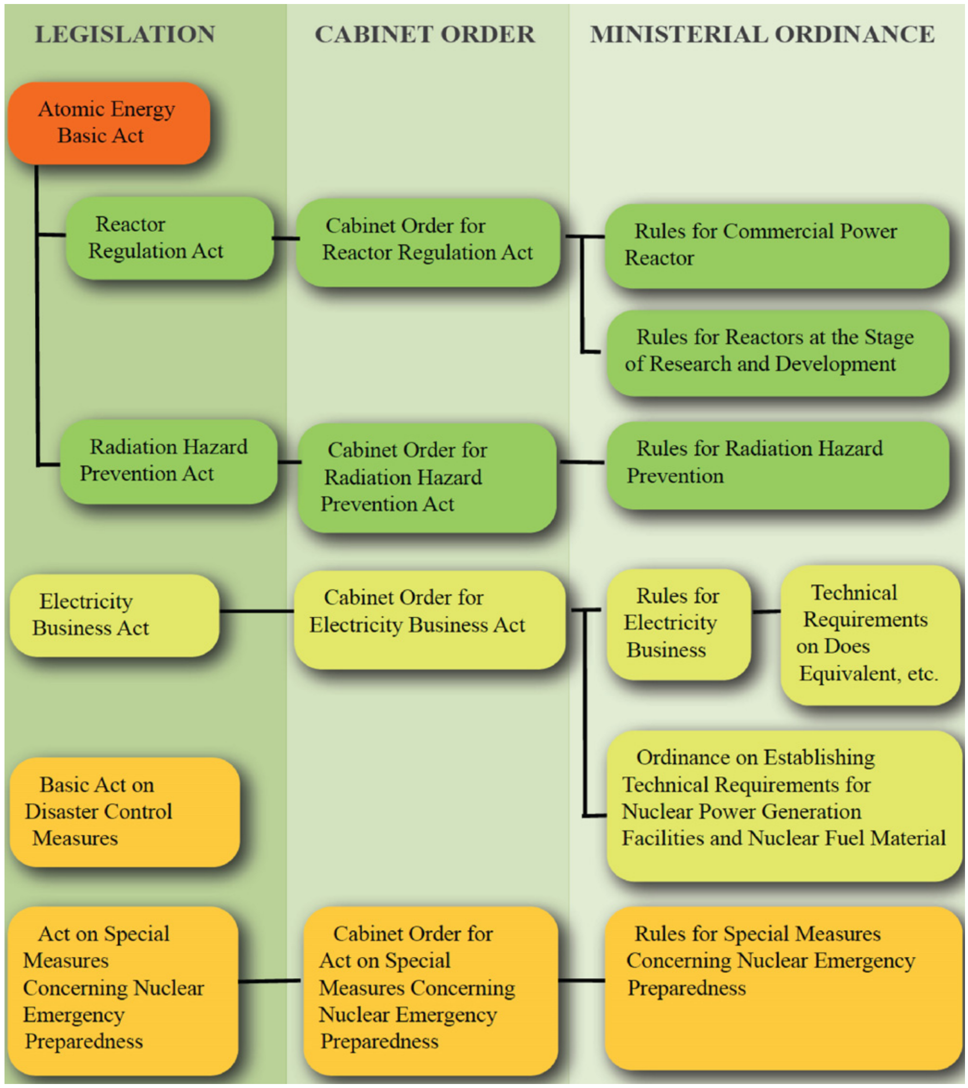


Fig. 3. Main legal structure of safety of nuclear reactor facilities in japan.

Sources: [1,48].

meetings. The experts in those groups lack of independence during the process of nuclear safety rulemaking transcripts of the meetings show members rarely challenged one another. During nearly four years of panel discussions, these experts focused on the plants' ability to withstand shaking, and measures of geological fault lines. Concern about nuclear plants being vulnerable to tsunami waves that have battered Japan following major quakes came up just once [9].

Even worse, NISA depended also relied on the nuclear industry itself to develop proposals and rules [3,4,9]. As a result, the nuclear safety rules reflect more the demand of nuclear industry than the nuclear safety requirements [38]. In the most serious case, TEPCO told NISA that sea waves at the spot would not exceed 5.7 m in a one-page safety guideline submitted in December 2001. According, NISA approved the Fukushima Daiichi nuclear plant was designed to withstand 5.7 m sea waves. However, on March 11, 2011, the water reached 14 meters above sea level at the plant, shutting down the electricity of cooling system of the reactor, and caused the nuclear disaster at Fukushima Daiichi nuclear station. TEPCO's safety proposal did not include anything about its data or assumptions of earthquake size and location – vital details to determine whether the calculations made sense. NISA neither demanded the information nor scrutinized the guidelines TEPCO used in its calculations. If regulators had looked, they would have found that 22 of the 35 people on the committee that wrote the guidelines had strong ties to the nuclear power industry. Among them, three were from TEPCO and one was from an affiliate of the utility; 13 more were from Japan's other electric power companies [9].

3. U.S. and China's nuclear safety regulatory

Nuclear regulatory failures are no respecters of boundaries. The China's nuclear safety regulation is fragile, whereas U.S. nuclear safety regulation is still need to be improved [10,49,50].

3.1. Weaknesses of China's nuclear regulatory system

China is currently building 27 new reactors – over 40% of the total number of reactor being built nuclear reactors worldwide. However, China has yet to establish an effective administrative system to be commensurate with the leader of reactors under construction.

3.1.1. Rules of law

China still has no specific atomic energy law to govern nuclear energy. In contrast, Japan's *Atomic Energy Basic Law* was enacted

Table 1
Law and regulations related to nuclear energy in China.

Regulations and rules	Enacted year
Law	
The Law on Prevention and Control of Radioactive Pollution	2003
Regulation	
Regulations of the PRC on Nuclear Materials Control	1987
Regulations of the PRC on the Control of Nuclear Export	1997, revised 2006
Regulations of the PRC on the Control of Nuclear Dual-Use Items and Related Technologies Export	1998, revised 2007
Regulations on Radiological Protection from Radiological Isotopes and Ray Devices	2005
Rule	
Rules for the Implementation of Regulations on Nuclear Materials Control	1990
Rules on Physical Protection for Nuclear Materials International Transport	1994
Rules on Inspection of Nuclear Materials Control	1997
Rules on Security of Nuclear Power Plants	1997
Rules on Radioactive items import and export license application and cooperation safeguards	2002

Sources: [54].

in 1955. *The Law on Prevention and Control of Radioactive Pollution*, enacted in 2003, only focuses on radioactive pollution in China [51]. Much of the nuclear safety regulations, rules and guidance were issued a decade ago, and do not meet current standards [51,52] (see Table 1).

3.1.2. Regulatory capture

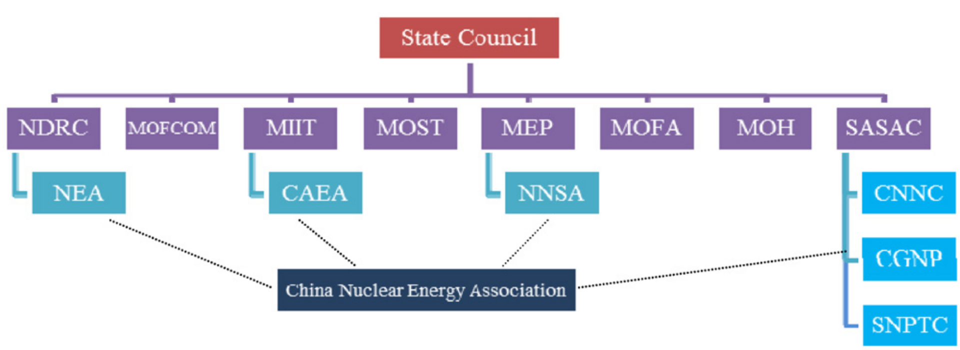
China's nuclear regulatory system has been fragmented among multiple agencies (see Fig. 4). The three main governmental oversight agencies are National Energy Administration (NEA), China Atomic Energy Authority (CAEA), and the National Nuclear Safety Administration (NNSA) [22,51,53,54]. NNSA, an agency responsible for nuclear safety, lacks the power, staff and money to implement its regulatory charter. In our view, this easily leads to NNSA come to be dominated by the industries regulated.

Currently, the NEA, rather than the NNSA has the most authority among those agencies related to nuclear safety. The NEA is a division of National Development of Reform Commission (NDRC), which has broad administrative and planning control over the Chinese economy and energy. In contrast, NNSA is a division of Ministry of Environmental Protection (MEP). Although MEP has been granted cabinet voting power since 2008, the environmental protection sector was of lower priority, in the Chinese "economy-development-centered" political atmosphere. The NEA is responsible for formulating programs, guidelines and regulations related to nuclear security, and licensing nuclear power plants which meet nuclear safety requirements. The NNSA's principal responsibilities limit to formulating environmental regulations related to civilian nuclear installations, reviewing technical standards of nuclear safety, and supervising on radioactive sources (production, import, export, sale, transportation, storage and disposal) [22,51,52,55].

NNSA is a division of the MEP, several steps removed from the Chinese State Council. However, the major nuclear energy companies are state own companies – the China Guangdong Nuclear Power Group (CGNPG), the China National Nuclear Corporation (CNNC), and the State Nuclear Power Technology Corporation (SNPTC) – reported directly to the State Council. NNSA has about 50 people to oversee 13 operational reactors (10.8 GW by end of 2010) in operation. Compared to this, the U.S., France and Japan employ about 40 people with $10 million per GW of nuclear power [53].

3.1.3. Control of corruption

The officials revolving between nuclear agency and nuclear utilities are not viewed as a form of corruption in China. This is due to the three main nuclear operators are state-owned companies, ranking the ministry-level in China's bureaucratic system as similar as NEA, CAEA, and NNSA. However, China is advised to maintain nuclear safeguards in a business culture where quality and safety are sometimes sacrificed in favor of cost-cutting, and corruption. Worldwide Governance Indicators (WGI) show China rated 155 in control of corruption in 2010, among 223 countries or regions [37]. Indeed, corruption has been occurred in nuclear construction. For



Notes: MOFCOM – Ministry of Commerce
MIIT –Ministry of Industry and Information Technology
MOST –Ministry of Science and Technology,
MEP – Ministry of Environmental Protection
MOFA –Ministry of Foreign Affairs
MOH –Ministry of Health
SASAC –State-owned Assets Supervision and Administration Commission

Fig. 4. Structure of China's nuclear administrative system.

example, Kang Rixin, the former chief of CNNC was sentenced in 2010 to life in prison for accepting at least $1 million in bribes.

3.2. United States nuclear regulatory system

In general, the regulatory system in the U.S. does a better job than its counterparts in China and Japan. Above all, the U.S. has established a mature nuclear safety law and regulation system. In addition, U.S. also separated the government's roles as promoter and regulator of nuclear nearly since the mid-1970s. Currently, the U.S. Department of Energy promotes nuclear power while the U.S. Nuclear Regulatory Commission (NRC) handles safety.

However, U.S. still faces the "revolving door" issue. NRC has the expertise and resources – a staff of 4000 and one of the highest densities of Ph.D.'s in government – to do a better job. However, the evidence suggests NRC is not effectively enforcing regulations [50]. The NRC is like a prep school for many of these guys, because they know they've got a good shot at landing much higher-paying work with the people they're supposed to be keeping in line. They're not going to do anything to jeopardize that [50]. Therefore, the NRC's regulatory struggles from a degree of regulatory capture (there are some instances of undue influence) and particularly from the weak enforcement of existing rules [10,38].

4. Recommendations

In some sense, the difference between Japan and other countries with weak nuclear regulatory might be luck. A lot of efforts are urgent to fix nuclear regulatory, especially the followed two areas.

Above all, governments of the 29 countries with nuclear energy should imminently be undertaking an in-depth review of the country's regulatory system. In those thoroughly review, three things are more urgent:

(i) It is time close the "revolving door" related to nuclear energy. Given there is always a limited group of people participates in highly nuclear complex industry [50], some experts move between the public and private sectors should be refrained by laws. Laws should be improved to strictly restrict revolving door. Personnel of nuclear regulatory agency must be subject to certain conflict of interest restrictions on private employment activities even after they leave nuclear agency.
(ii) Responsible for keep reactor safe should be rest on an independent agency, which is a legitimate, credible and authoritative regulator.
(iii) The idea of nuclear safety rule without border should be set up. Internal peer-review should become a practice. A country should not reduce the nuclear safety standards on the ground of its specific condition.

In addition, U.S. and China should take a leadership role in shaping more effective nuclear safety regulatory system. As the owner of most reactors in operation, U.S. should set an example of nuclear safety for other 28 countries in reactor operating. As a leader of proposed reactors in the world, China should also take a leader of nuclear safety for those countries with construct nuclear reactors. Meanwhile, the two countries should joint developed the safety standard for the third generation of reactor, which include improved fuel technology, superior thermal efficiency, passive safety systems and standardized design for reduced maintenance and capital costs [56]. As of May 2011, the AP1000 reactors, developed by U.S., built at Sanmen, Zhejiang in north China are the only commercial units in the world to have started construction [57]. U.S.–China Strategic and Economic Dialogue should facilitate the nuclear safety regulation cooperation between the two countries.

Nuclear accident knows no boundaries. Strengthening our nuclear safety regulation is not an option but an imperative, thus ensuring that the 433 operational units of reactor run safely, as well as 65 proposed ones.

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